SAR IMAGING GEODESY– RECENT RESULTS FOR TERRASAR-X AND FOR SENTINEL-1

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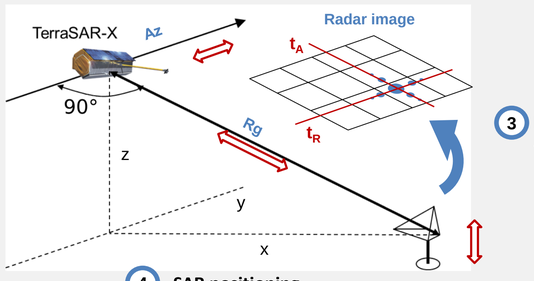
1. Imaging Geodesy Concepts

1 Orbit determination
Very high requirements [mm-cm]
Realizes reference frame (ITRF08)

2 Image formation
Accurate & time consistent SAR instrument
Accurate & time consistent processor



3 Point target analysis
t_A, t_R at subpixel level (<1/100th)

4 SAR positioning
t_A, t_R & wave propagation
& earth dynamics → 2D coordinates (Rg, Az)
Second geometry → 3D coordinates (x, y, z)

Eineder, M., Minet, C., Steigenberger, P., Cong, X., Fritz, T., Imaging Geodesy – Toward Centimeter-Level Ranging Accuracy With TerraSAR-X, IEEE Transactions on Geoscience and Remote Sensing 49, pp. 661-671, 2011

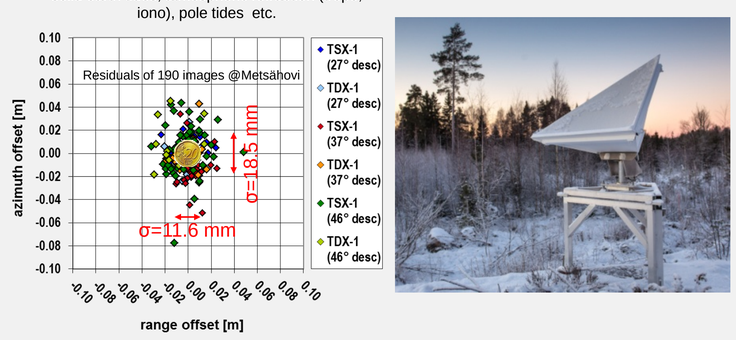
- Precise calibration of SAR system
- Geometrically accurate processing of SAR data
- Comp. of signal propagation by GNSS measurements or models
- Compensation of Earth dynamics
- Use of multiple acquisitions (different geometries)

→ **Accurate absolute 2D (3D) positioning**

2. TerraSAR-X Results

TerraSAR-X Absolute 2D Positioning Accuracy

TSX 2D positioning accuracy of a CR, corrected for solid earth tides, atmospheric refraction (tropo, iono), pole tides etc.

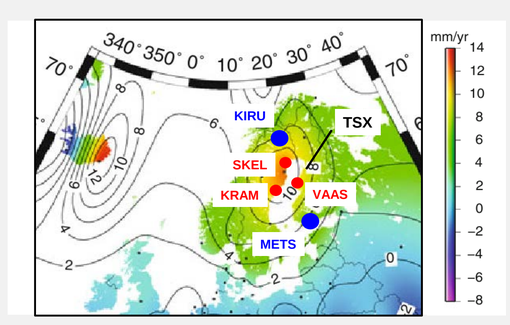


Gisinger C, Balss U, Pail R, Zhu XX, Montazeri S, Gernhardt S, Eineder M., Precise Three-Dimensional Stereo Localization of Corner Reflectors and Persistent Scatterers With TerraSAR-X. IEEE Transactions on Geoscience and Remote Sensing, 2014

- Long time experiments running since 2012 in Wettzell, Metsähovi, GARS O'Higgins
  - A 1.5 m corner reflector can be localized to within 1-2 cm in the slant range plane and about 6 cm in 3D ITRF08
  - Accuracy depends on SCR (size), orbit accuracy, troposphere information (GNSS, ECMWF-model) , ionosphere

3. New Geodetic Applications

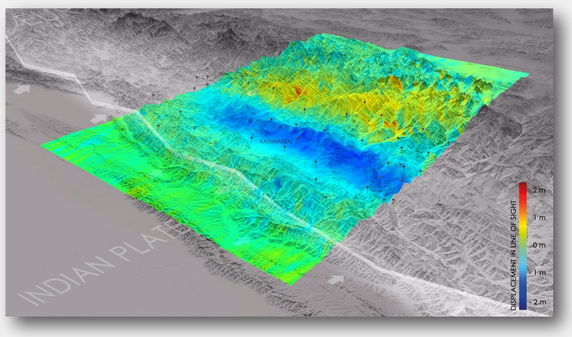
Displacement: mm / year



V_{North}	V_{East}	V_{Height}
TerraSAR-X (70 PS)		
12.8 ± 2.1	14.8 ± 2.4	5.9 ± 2.4
[1]GNSS		
Skelefteå		11.0 ± 0.5
Kramfors		10.1 ± 0.5
Vaasa		9.3 ± 0.5
[2] Absolute Gravimetry		
Skelefteå		11.1 ± 1.8
Kramfors		8.5 ± 1.8
Vaasa		7.2 ± 1.8
IGS GNSS Stations: METS, KIRU		
12.8	19.9	4.5
14.6	15.9	6.5

Post-glacial uplift of Finland measured in Oulu with TerraSAR-X

Gisinger, S. Montazeri, U. Balss, X. Cong, S. Hackel, X. Zhu, R. Pail, M. Eineder Applying geodetic SAR with TerraSAR-X and TanDEM-X, TerraSAR-X / TanDEM-X Science Team Meeting, 2016



Ground displacements caused by the 7.8-magnitute earthquake that struck Nepal on 25 April 2015. Data: Sentinel-1A.

More examples:
- **Tue 15:00 h Poster Session 1, Application and Performance of Geodetic Corrections for InSAR Processing, F. Rodriguez Gonzalez et al.**
- **Wed 7th of June in Nokia-Sali 09:00 h: "Towards the Integration of Automatically Generated SAR Ground Control Points into InSAR Stacking Techniques", S. Montazeri et al.**

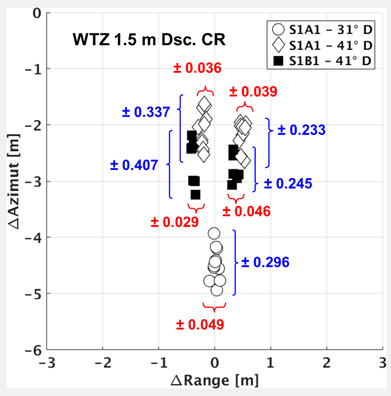
4. The Australian (GSA) CR Array

M. C. Garthwaite, M. Thankappan, M. L. Williams, S. Nancarrow, A. Hislop and J. Dawson, Corner reflectors for the Australian Geophysical Observing System and support for calibration of satellite-borne synthetic aperture radars, IEEE IGARSS, 2013

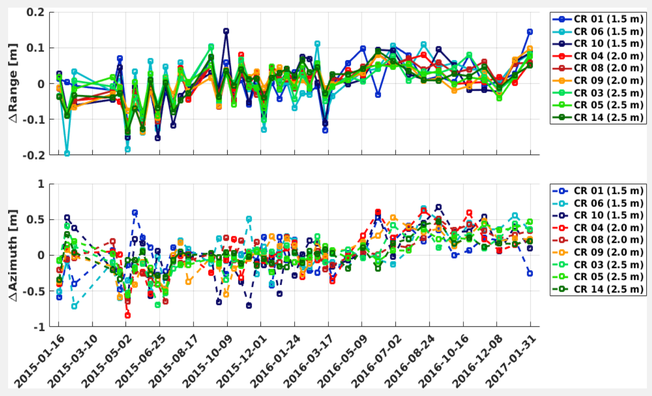
Several CRs of different sizes distributed over Sentinel-1 beams and within bursts.

Data are analyzed and recipes for CR placement and for geodetic SAR with Sentinel-1 are developed within ESA Contract No. 4000119113 "Fiducial Reference Measurements for SAR" with Uni Zürich (D. Small & A. Schubert) and N. Miranda (ESA).

5. First results with Sentinel-1: Exciting Potential!



Sentinel-1 analysis in Wettzell (1.5 m CR) shows good potential, but varying systematic errors depending on S1A/S1B and beams and burst time.



Australian CR field is excellently suited to analyze and possibly calibrate residual geometric effects in Sentinel-1 A/B.

6. Summary & Outlook

This poster summarizes work performed by the DLR-TUM "Imaging Geodesy" study group co-funded by the German Helmholtz Association 2012-2016.

- The study group has developed methods for 3D positioning of objects from TerraSAR-X with centimeter accuracy
- Many new geodetic applications are currently exploited, e.g. for mapping, land motion, interferometry, etc.
- The work is continued with University of Zürich and applied to Sentinel-1 data under ESA contract. First results clearly indicate the potential for comparable results, taking into account the reduced resolution